# Biodiesel and Renewable Diesel Emissions Study VOC, Carbonyl & $N_2O$ Emissions

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# Acknowledgements

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Organic Analysis

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# Engines and Fuels

| Make/model/year | Emission Control Devices | Test fuels | Analyses |
|---|---|---|---|
| 2000 Freightliner C15 Caterpillar | | ULSD diesel,<br>Soy-based biodiesel (S20, S50, S100),<br>Animal-based ( A20, A50, A100),<br>Renewable diesel (R20, R50, R100) | VOC<br>Carbonyl<br>N2O |
| 2006 International ISM 370 | EGR | ULSD diesel,<br>Soy-based biodiesel (S20, S50, S100),<br>Animal-based ( A20, A50, A100), | VOC<br>Carbonyl |
| 2008 Freightliner Mercedes Benz MBE 4000 | DOC,<br>DPF,<br>EGR | ULSD diesel,<br>Soy-based biodiesel (S20, S50, S100),<br>Animal-based ( A20, A50, A100), | VOC<br>Carbonyl |

# Emissions Analyses

- Speciated non-methane hydrocarbons  (NMHC)
- Carbonyl compounds
- Nitrous Oxide (N2O)

# Instrumentation

| **Analysis** | **Sample Container** | **Instrument** |
|---|---|---|
| NMHC | Tedlar Bag | Gas Chromatograph (GC) with flame ionization detector (FID) |
| Carbonyls | DNPH* Cartridge | High performance liquid chromatograph (HPLC) with UV detector |
| $N_2O$ | Tedlar Bag | Fourier transform infrared spectrometer (FTIR) |

*** Sampling cartridge impregnated with 2,4-dinitrophenylhydrazine**

# Speciated Non-Methane Hydrocarbon Analysis

- Tedlar bag samples analyzed by 2 GC/FIDs, connected in parallel
  - *Light-end GC:  C1 to C5 HCs*
  - *Mid-range GC:  C6 to C12 HCs*
- Liquid nitrogen trapping of sample yields FID detection limits to very low ppbC

**Dual Gas Chromatograph**

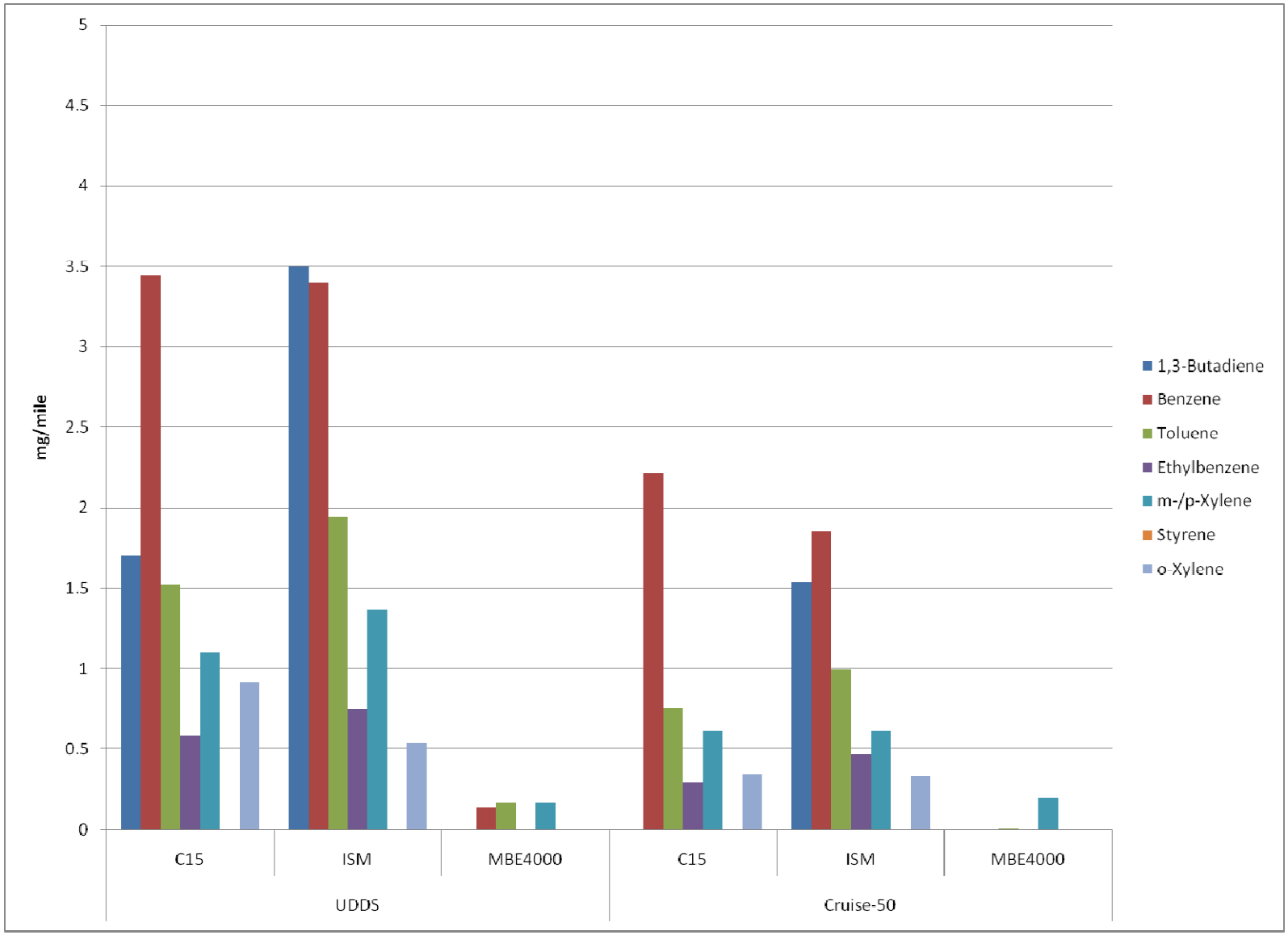
**H2 Generator** **Mid-range GC** **Light-end GC**

# Speciated Non-Methane Hydrocarbon Analysis

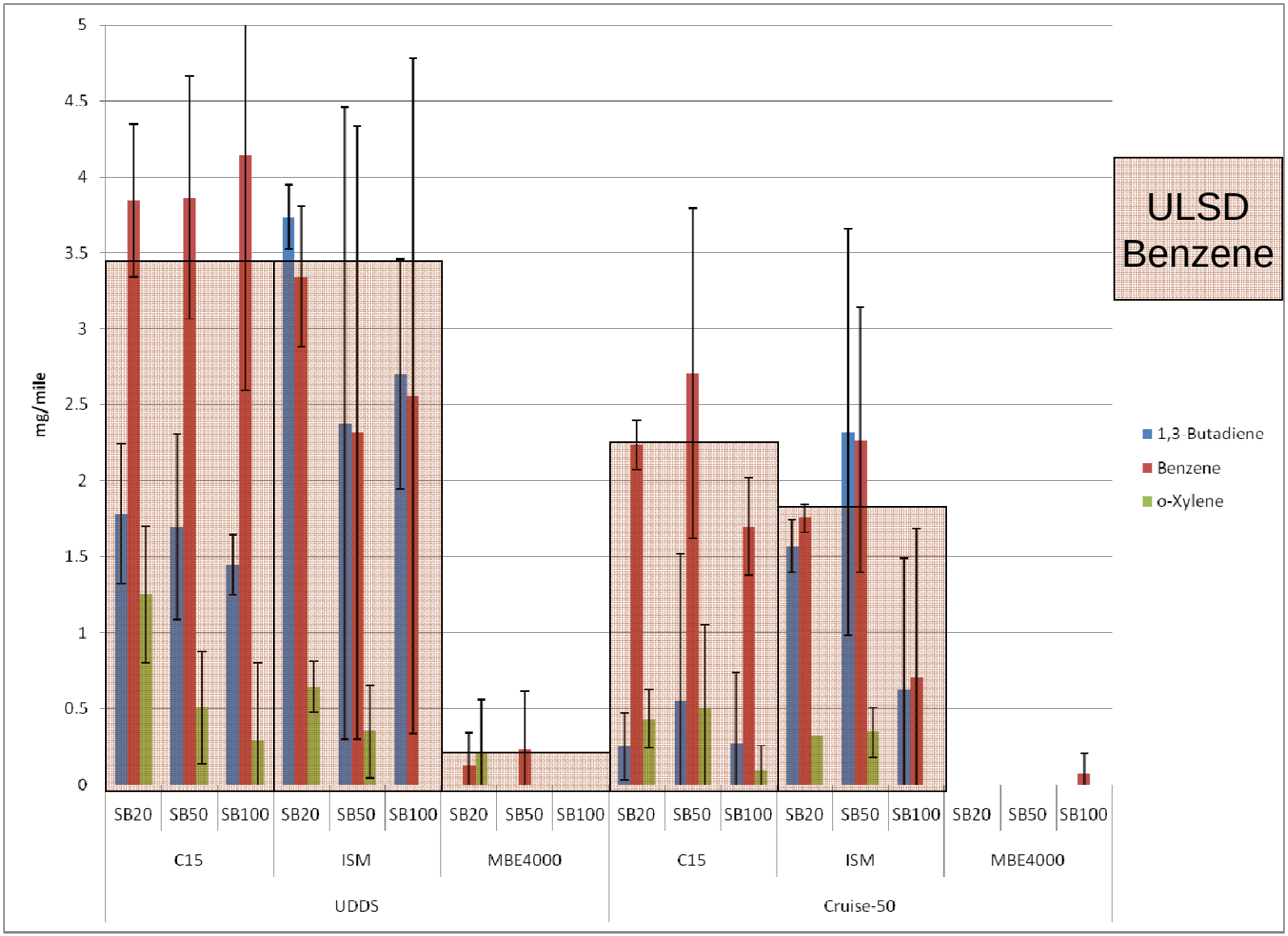
- Compounds reported for this study:

***1,3-butadiene***
***benzene***
***toluene***
***ethylbenzene***
***m-/p-xylene***
***styrene***
***o-xylene***

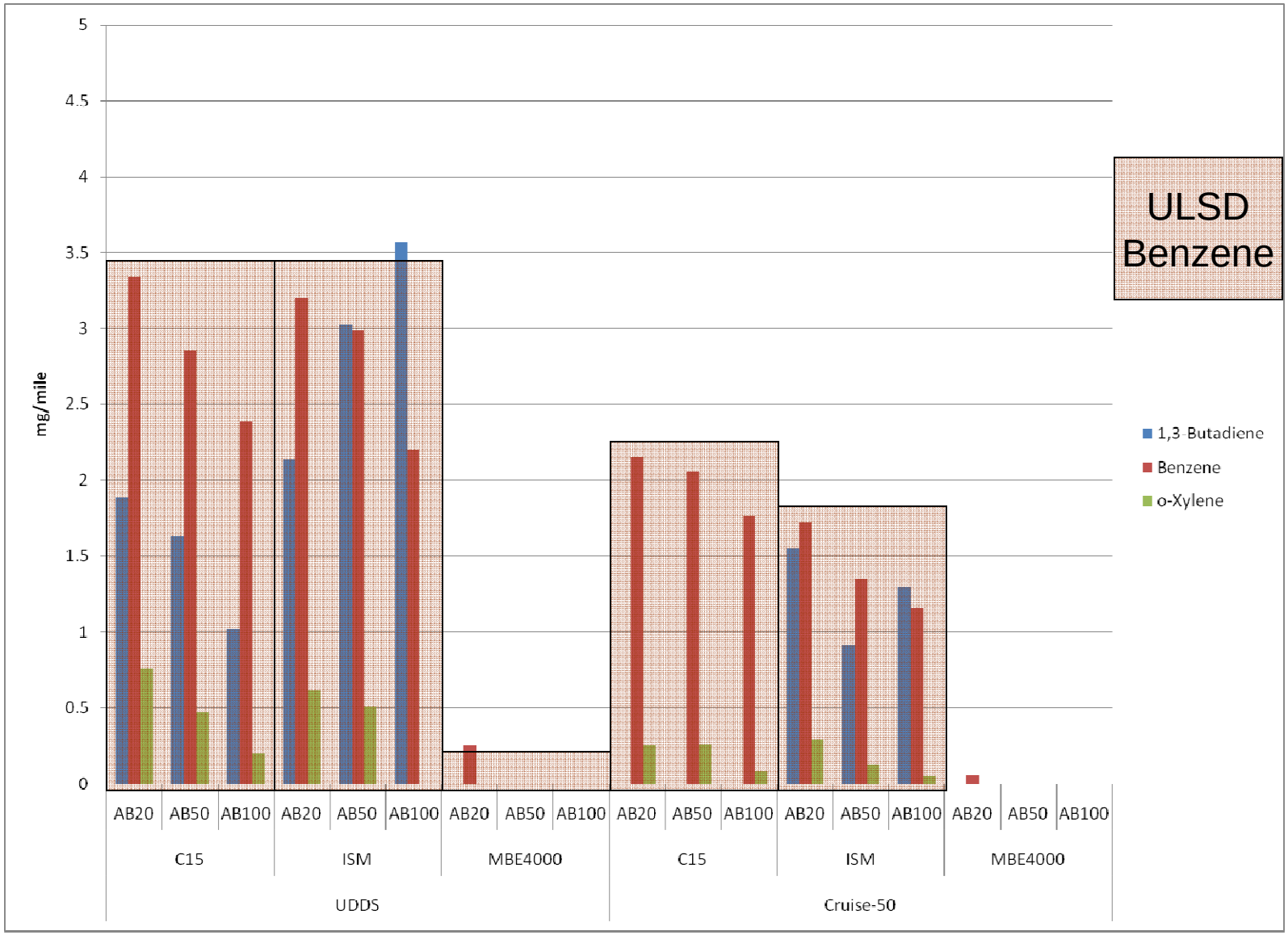
# Toxic VOC - ULSD



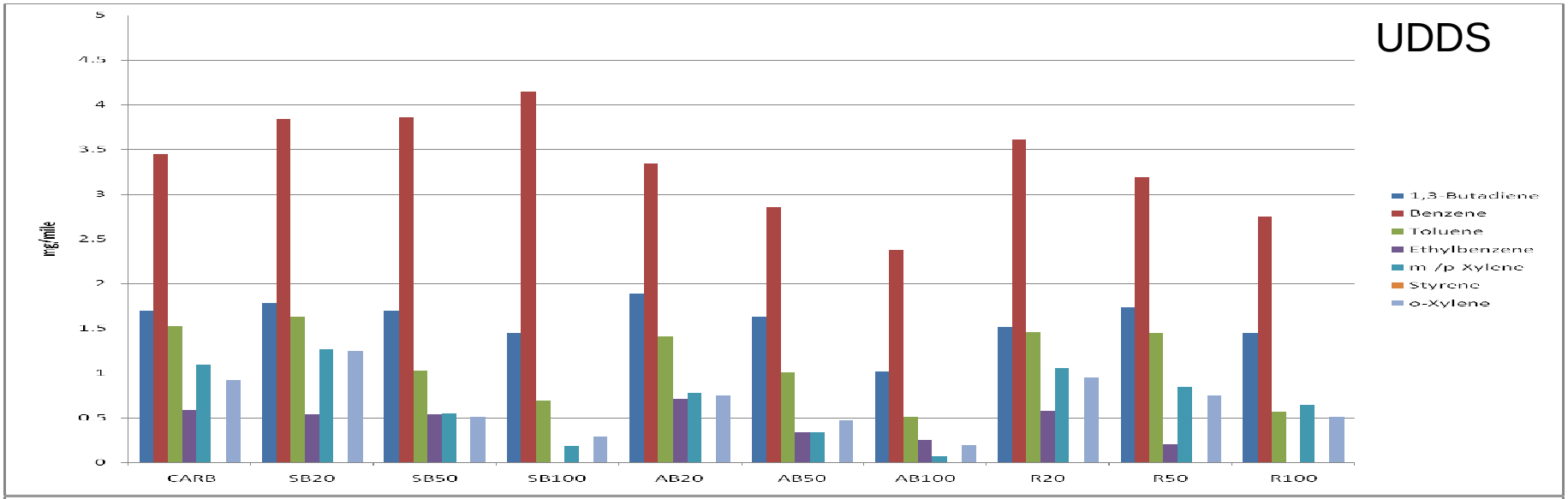
# Toxic VOC - Soy Biodiesel

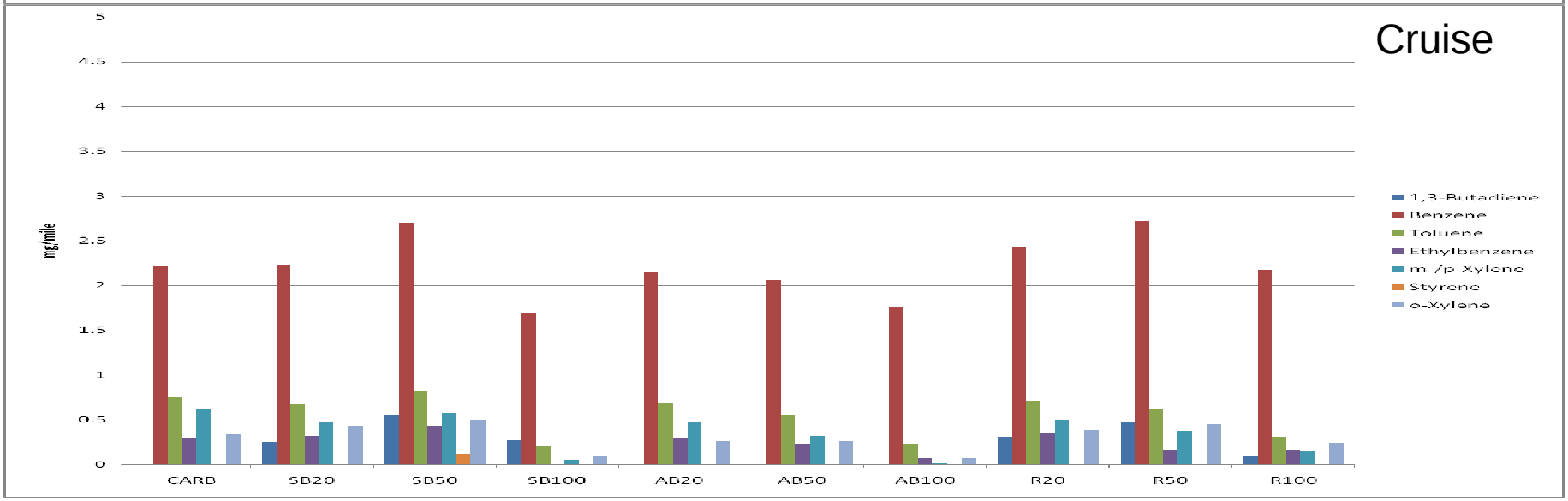


# Toxic VOC - Animal Biodiesel

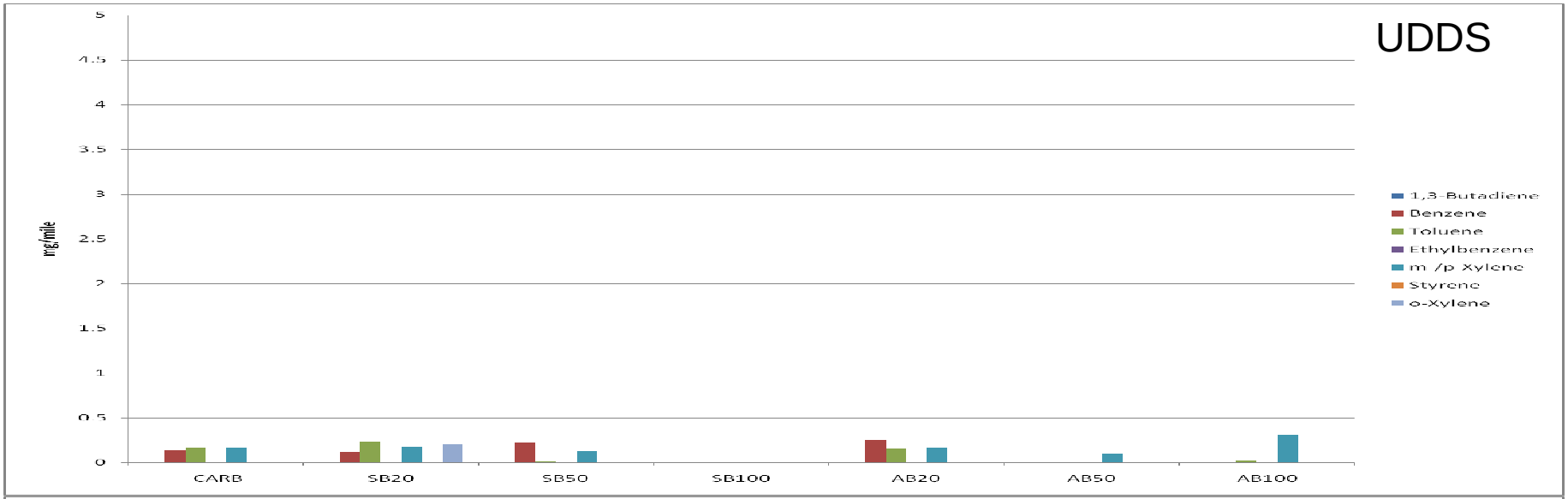


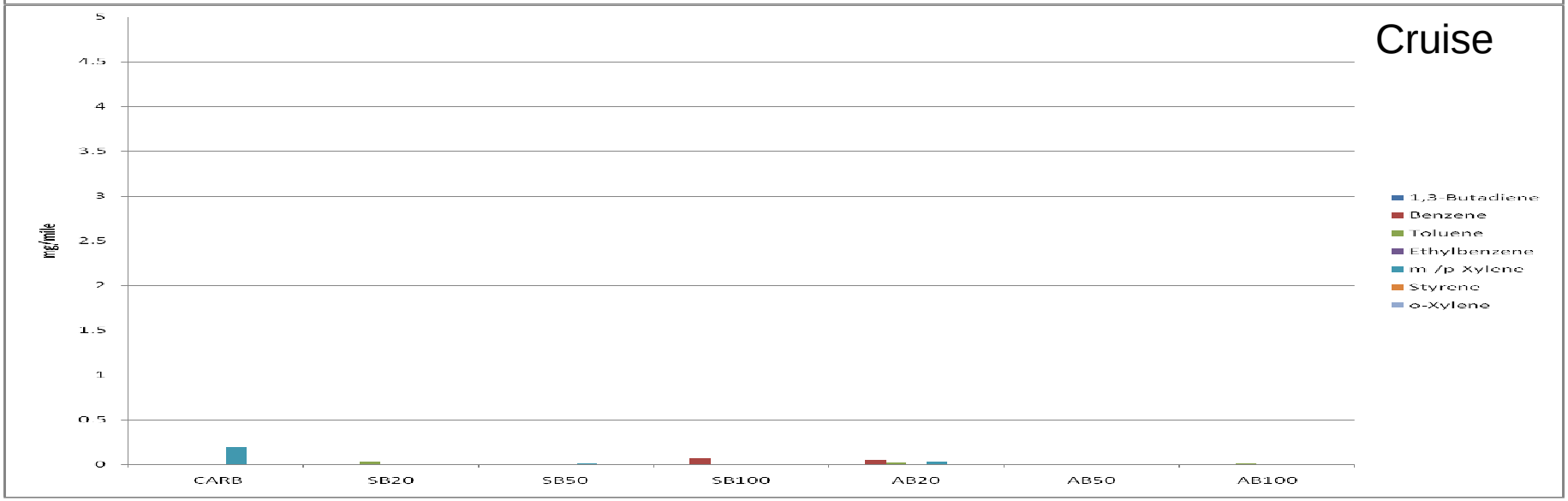
# Toxic VOC -C15



# Toxic VOC -MBE4000

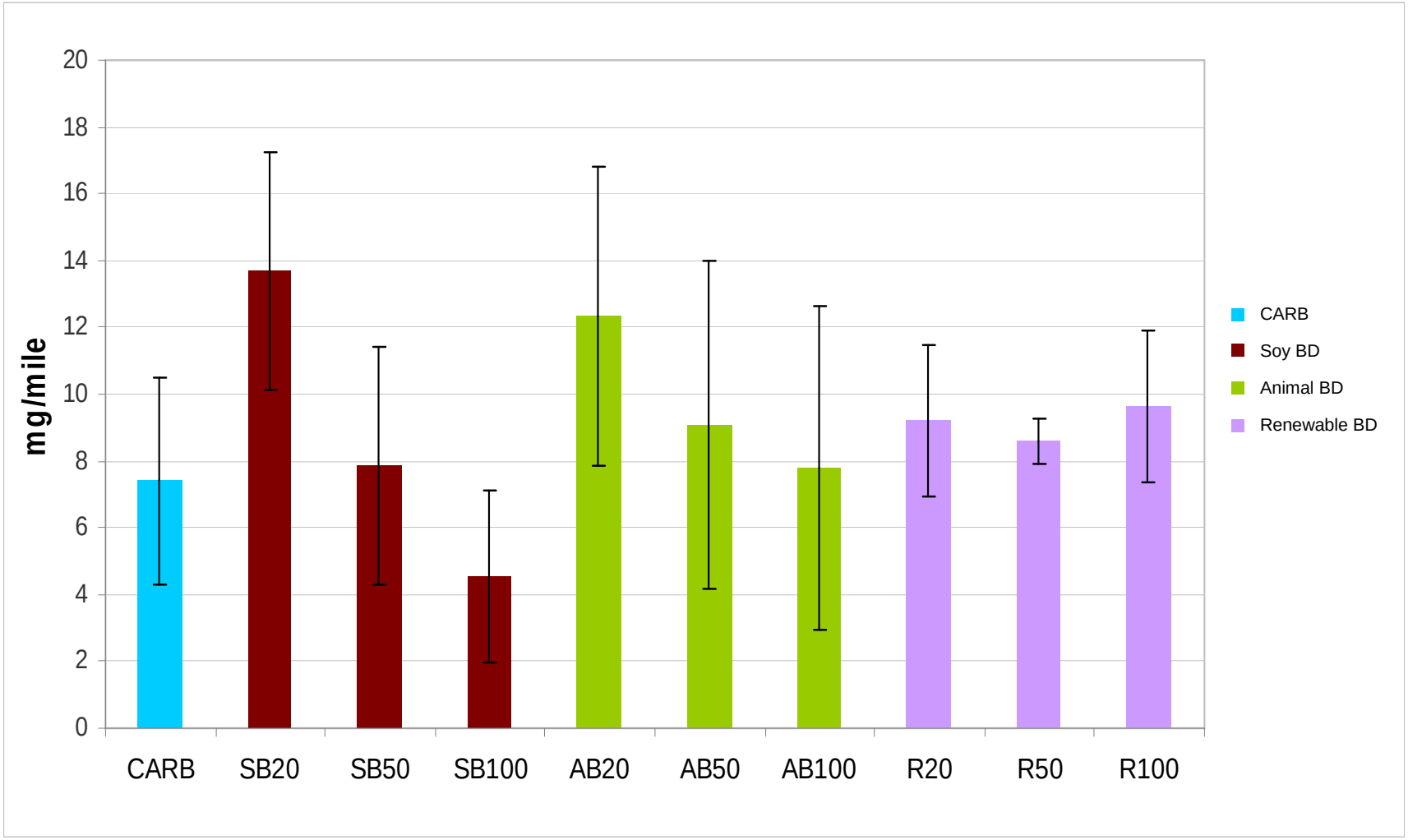


# NITROUS OXIDE ANALYSIS

- Tedlar bag samples analyzed by Fourier transform infrared spectroscopy (FTIR)
  - 10-Meter, folded path IR cell

# $N_2O$ – C15 Engine



# Carbonyl Analysis (Aldehydes and Ketones)

- Carbonyl group derivatized by DNPH in sampling cartridge*

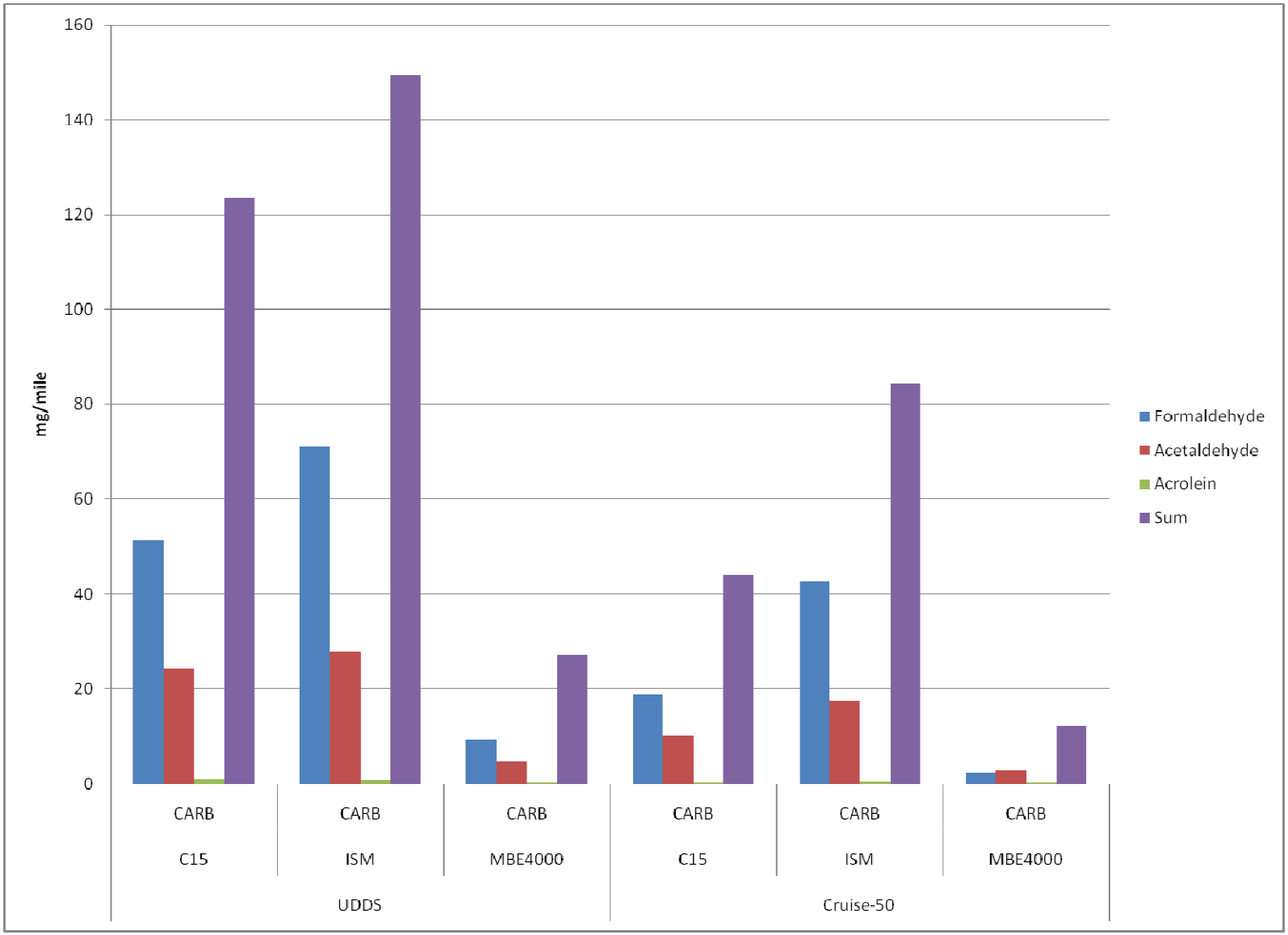
- Cartridges flushed with solvent to extract carbonyl compounds

- Solution analyzed by high performance liquid chromatograph (HPLC) with UV detection

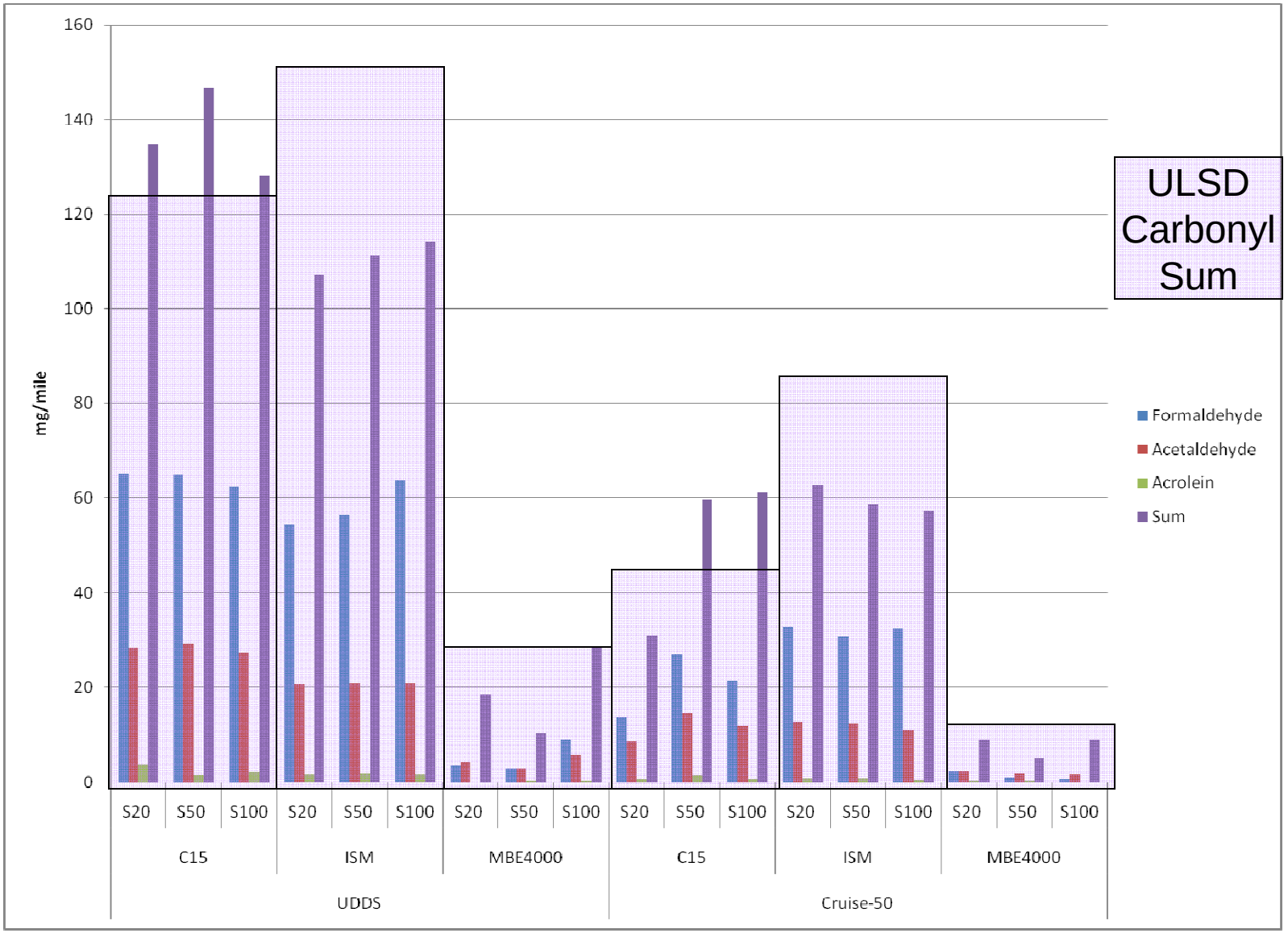
# Carbonyl Analysis (Aldehydes and Ketones)

- This method measures:
  - formaldehyde
  - acetaldehyde
  - acrolein*
  - 10 Other carbonyls (to $C_6$)

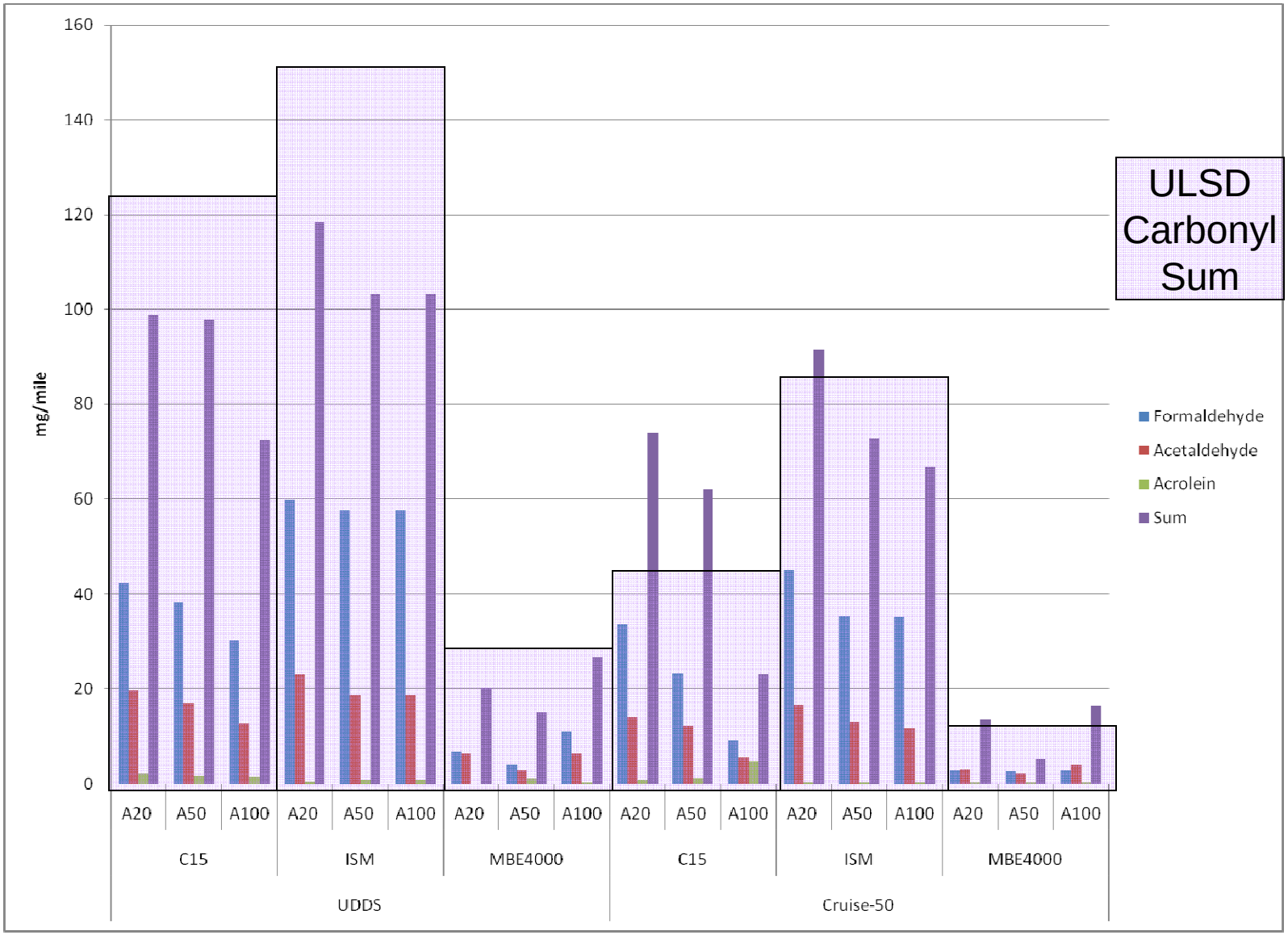
# Carbonyl - ULSD



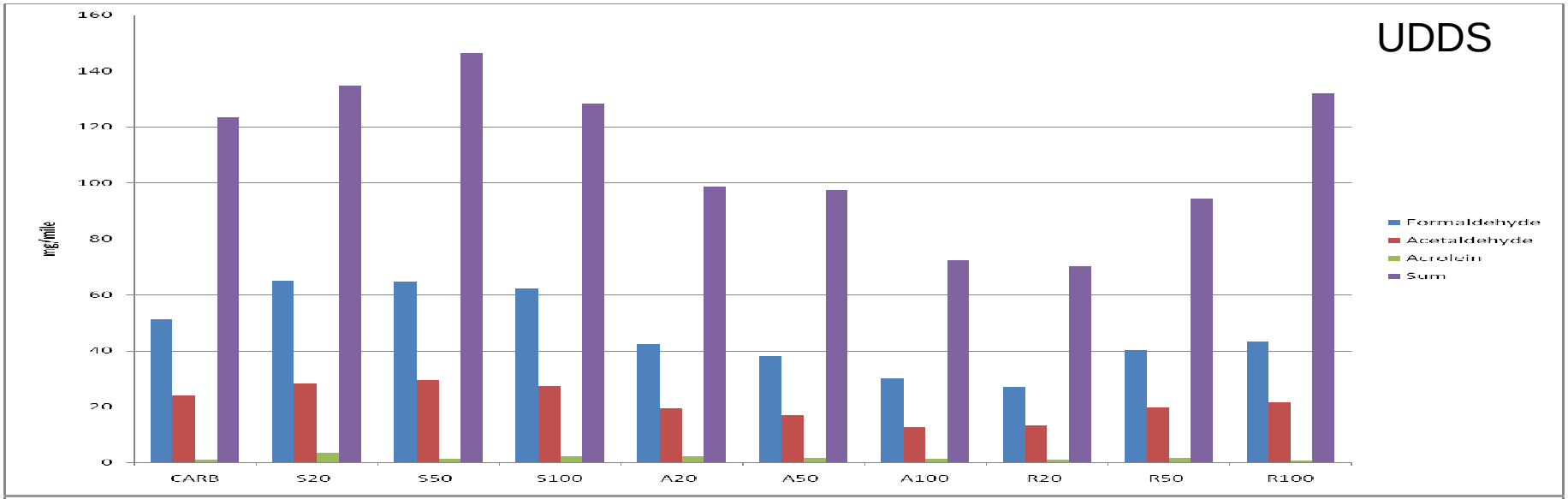
# Carbonyl - Soy Biodiesel

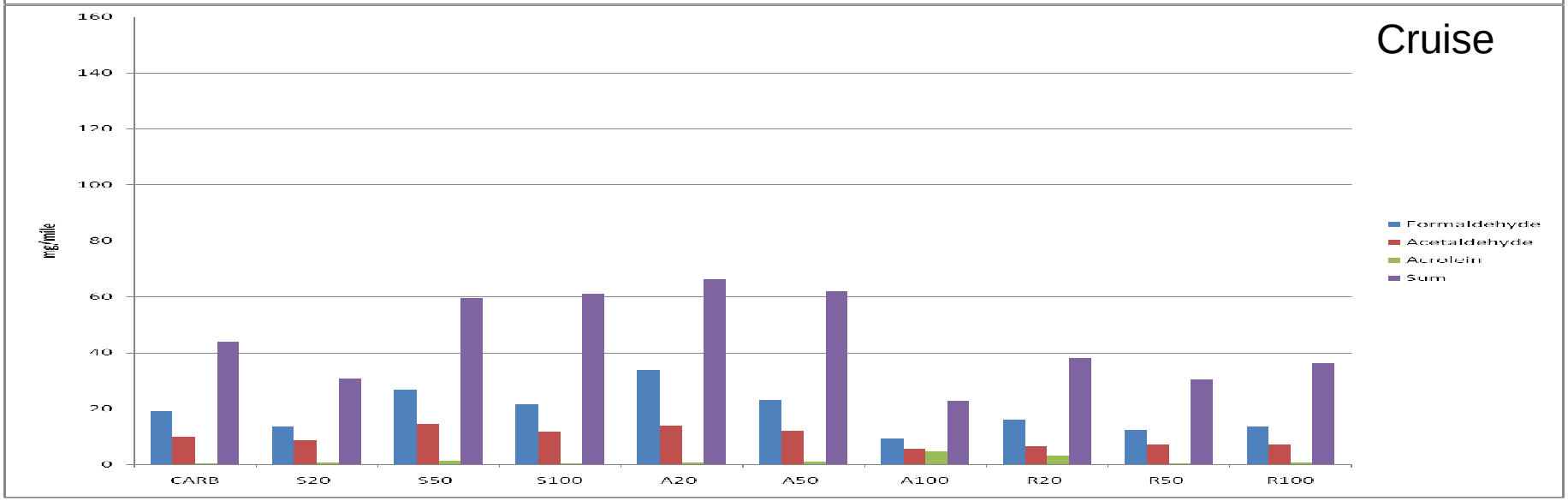


# Carbonyl - Animal Biodiesel

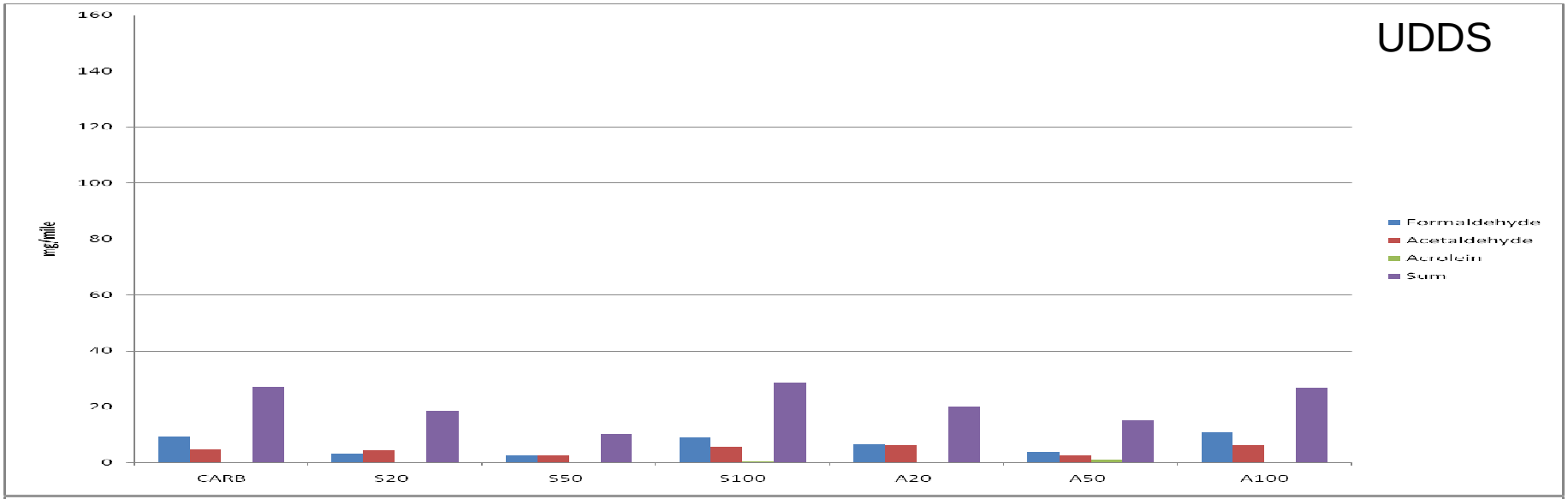


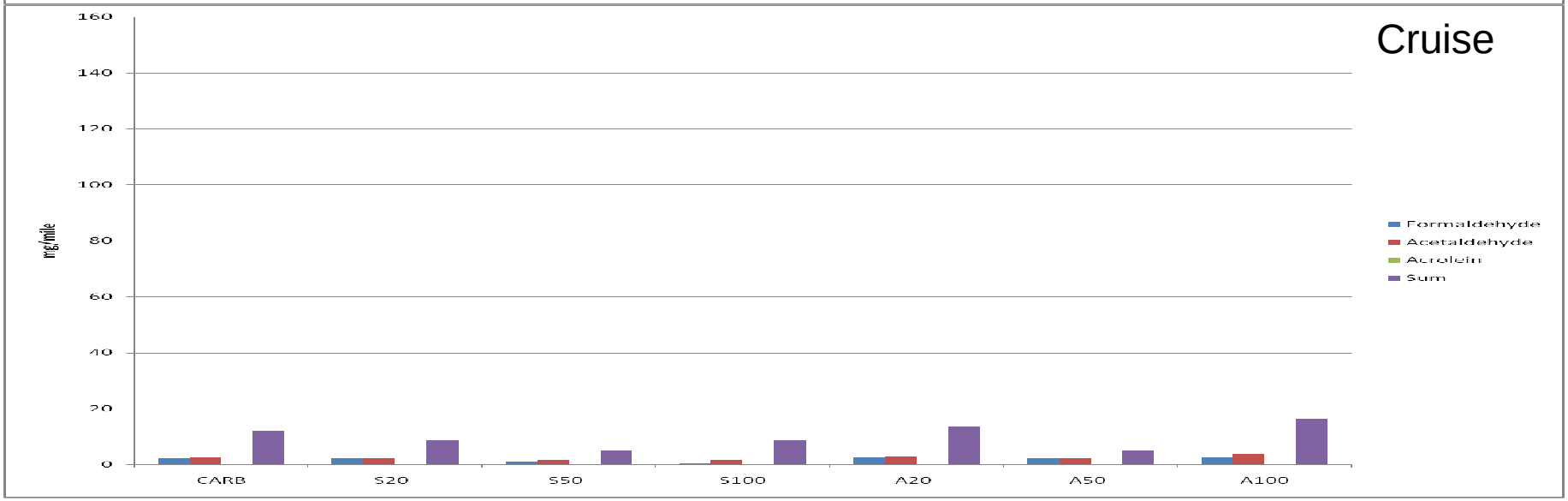
# Carbonyl-C15



# Carbonyl-MBE4000



# Summary - VOC

- Soy Biodiesel
  - No significant VOC increase versus ULSD Fuel
  - No trend with regard to increasing Biodiesel fractions
- Animal Biodiesel
  - Modest VOC decrease versus ULSD Fuel
  - VOC reduced with increasing Biodiesel fractions
- Renewable Biodiesel
  - Modest VOC decrease in UDDS cycle versus ULSD fuel but not in cruise
  - VOC reduced with increasing Biodiesel fraction in UDDS but not in cruise

# Summary – N2O

- No significant change in N2O emissions is observed for any fuel blend

# Summary - Carbonyl

- Soy Biodiesel
  - No significant changes versus ULSD Fuel
  - No trend with regards to increasing Biodiesel fractions
- Animal Biodiesel
  - Modest decrease versus USLD Fuel in UDDS Cycle only
  - emissions reduced with increasing Biodiesel fractions.
- Renewable Biodiesel
  - No significant changes versus ULSD

# Summary - Engines

- VOC
  - C15 and ISM engines perform similarly to each other under all fuel scenarios
  - MBE4000 emits ~ <1/10$^{th}$ of the average of C15 and ISM engines
- Carbonyls
  - C15 and ISM engines perform similarly to each other under all fuel scenarios
  - MBE4000 emits ~ <1/6$^{th}$ of the average of C15 and ISM engines